

STEWART LAKE WATERFOWL MANAGEMENT AREA

REPORT ON THE SEDIMENT SAMPLES COLLECTED FROM STEWART LAKE, UTAH DURING 2002

**J.W. YAHNKE
LAND SUITABILITY AND WATER QUALITY GROUP
TECHNICAL SERVICE CENTER
DENVER, COLORADO
JANUARY 2004**

Report on Sediment Samples Collected from Stewart Lake, Utah in 2002

Report Summary

This report addresses sediment samples collected by personnel of the Bureau of Reclamation in April, August, September, and October 2002 at Stewart Lake, Utah, in conjunction with the effort to remediate its selenium contaminated sediments. The April samples were collected as a pre-flood baseline. Surface samples were collected for analysis of total selenium from 20 permanent monitoring sites. Sediment depth profile samples were collected from 4 quadrants in site 21 for selenium speciation; surface samples were collected at 5 other sites for speciation. Because of low runoff in the spring of 2002, no flood water entered Stewart Lake from the Green River. Samples collected in August and September related to a 5-day (August 29 through September 2) controlled flood that was confined to 2 experimental plots constructed in the north end of Stewart Lake. Samples were collected for total selenium and speciation. The October samples consisted of the routine surface samples collected for total selenium analysis annually at 20 permanent monitoring sites in the lake.

At the 5 sites sampled for selenium speciation at the surface only, selenate was present in its highest at site 15, 25 percent of the total; it was between 10 and 20 percent at sites 7 and 10; and it was lowest at sites 1 and 16 at less than 5 percent. Site 16 had been covered by a pool of ice formed by seepage shortly before sampling. Elemental selenium was predominant at 3 of the 5 sites, while selenite dominated at the other 2 sites. Elemental selenium was the dominant species in all surface samples from site 21, where it constituted between 40 and 50 percent of the total selenium. However, selenate was approximately 25 percent of the total in 3 of the 4 quadrants before lime was applied.

Lime was to be applied to the test plot at site 21 before the spring flood from the Green River in 2002. Samples were collected before and after the lime was applied to the 3-acre experimental plot. Application of the lime caused chemical reduction of oxidized species of selenium (selenate and selenite) and a 1-2 ppm increase in reduced (elemental) selenium. It also caused a reduction in total selenium in 3 of the 4 sites sampled; the reductions amounted to between 1.6 and 3 ppm. The lime application also resulted in a net reduction in soluble selenium, indicating that the application of lime would not result in additional leaching of selenium as had been planned.

The flood experiment was generally successful. There was a reduction in selenate in all layers of the sediments, although there was an indication that some had been converted to selenite and elemental selenium. Total selenium was reduced in the surface sediments and in layers between 12 and 24 inches deep, but increased in the 6-12 inch deep layer. There was no large increase in selenium in deeper sediments that would indicate that there had been selenium deposition.

A separate analysis of the difference in the results of the flooding experiment based on total selenium as analyzed in laboratories at the University of California at Riverside and the USGS in Denver indicated that the analytical results differ. The USGS analytical procedure is based on a more vigorous digestion. The USGS procedure gives progressively higher results as selenium concentrations increase. In other words, the difference in the 2 sets of results is concentration dependent.

The change in the mass of selenium in the 2 experimental flood plots was estimated. In both the small experimental flood plot and 1 quadrant of the larger experimental flood plot (site 21), there was a net removal of selenium. There was a removal of soluble selenium in all layers (6-inch layers to a depth of 36 inches) of the sediment at each site. There was also a significant decrease in insoluble selenium in 4 of the 6 layers at site 21 and a net decrease in the profile as a whole. There were layers of apparent deposition of insoluble selenium at each site. The layers of deposition appear to be primarily due to the timing of the end of the flooding during the experiment. Estimates of the mass change in the surface sediments (0-6 inches) of the small flood plot and 4 quadrants of the large flood plot that were sampled separately showed a high degree of variability. In the surface sediments of the north half of site 21, there was a small net increase in selenium in 1 quadrant and a large decrease in another quadrant at site 21; there were relatively consistent decreases in the small flood plot and the 2 quadrants in the south half of site 21. An analysis of the quality control data from a 2-year period (2001-2002) indicated that much of the variability could be due to random variation.

The surface samples from the permanent monitoring sites indicate that there was a small increase (0.3 ppm average) in total selenium overwinter from November 2001 to April 2002. There was subsequently a small decrease (0.2 ppm average) between April and October 2002. Overall there was no change in total selenium during 2002.

The long-term monitoring data (1995-2002) were analyzed for trends. There have been overall decreases in total selenium in 1997 and 2000 and an overall increase during 1998. Since 1995, there has been no measurable overall change in total selenium at the permanent monitoring sites in Stewart Lake. Beginning in 1998, concentrations of total selenium have been much higher in the north end of Stewart Lake than to the south. Individual observations can be classified into appropriate locations within Stewart Lake with a near 90 percent accuracy on the basis of total selenium concentrations. Areas in the north of the lake have a total selenium concentration in excess of 20 ppm (average 28 ppm), while areas to the south in the lake have a selenium concentration that is less than 20 ppm (average 12 ppm). The increase in selenium that occurred in Stewart Lake in 1998 was confined to its north end. As was noted in the 2002 sediment report, the initial increase in 1998 was apparently caused by the J2, J3, and J4 drains before they were diverted to the Green River. The seepage has maintained the elevated levels since then. However, there has also been no change in total selenium at sites located in the south end of Stewart Lake away from the seepage. The total selenium concentration in these sites with lower selenium remains well above the selenium cleanup goal of 4 ppm.

Table of Contents	
Section	Page
Summary	i
Table of Contents	iii
Introduction	1
2002 pre-flood Samples	1
April 2002	3
Lime	5
August 2002	7
Flooding Effects on Sediment Selenium	11
Surface Sediment Selenium	13
Sediment Selenium Profiles	18
Selenium Mass Changes in the Experimental Flood Plots	27
Selenium Variation in Sediment Samples	33
Permanent Monitoring Sites	35
April 2002 Selenium Profiles	35
Surface Samples at the 20 Permanent Monitoring Sites	40
Long-term Selenium Monitoring: 1995-2002	41
Conclusions	49
References	50
Appendix A – Sampling Reports (follow page 51)	A-1
Appendix B – 2002 Selenium Data	B-1
Appendix C – Discriminant Analysis: Canonical Scores and Classifications	C-1

List of Figures		
Number	Title	Page
1	Permanent monitoring sites at Stewart Lake, Utah, as of November 2001	2
2	Concentrations and percentages of 3 selenium species in surface sediments at 5 sites in Stewart Lake during April 2002	3
3	Soluble and insoluble selenite fractions at 5 sites in Stewart Lake during April 2002	4
4	Concentrations of 3 selenium species in surface samples collected at sites 21 during April 2002	4
5	Concentrations of total selenium and its species in sediments samples collected from Stewart Lake in April and August 2002	9
6	Changes in concentrations of total selenium and its species in samples collected from Stewart Lake in April and August 2002	10
7	Location of the 2002 Experimental Flood Plots at Stewart Lake	12
8	Concentrations of selected selenium species before and after the flood experiment in the USGS flood plot an Reclamation's experimental site 21	14
9	Changes in concentrations of various selenium species during the during the 2002 flood experiments at Stewart Lake	15

List of Figures (continued)

Number	Title	Page
10	Pre- and post-flood concentrations of total selenium and its soluble and insoluble fractions in the flood plot and sites 21 sediments in 2002	16
11	Organic-matter associated selenium concentrations and changes in the flood plot and site 21	17
12	Changes in the concentrations of 2 measures of total selenium in the flood plot and site 21	18
13	Post-flood total selenium profiles at sites 21 and FP	18
14	Pre- and post flood 2002 selenate and selenite concentrations at 2 sites in Stewart Lake	20
15	Changes in selenate, total soluble selenium and selenite in profiles at 2 sites at Stewart Lake during the 2002 flood experiments	21
16	Percent of soluble selenium reduction due to selenate	21
17	Pre- and post-flood concentrations and changes in organic selenium	22
18	Organic matter-associated selenium concentrations and changes during the flood experiment	23
19	Pre- and post-flood concentrations of elemental and 2 measures of total selenium at 2 sites at Stewart Lake during the 2002 flooding experiment	24
20	Changes in the concentrations of elemental, total insoluble, and 2 measures of total selenium at 2 sites at Stewart Lake during the 2002 Stewart Lake flooding experiment	25
21	Relationship between the UCR and USGS measures of total selenium	27
22	Total selenium profiles at sites 1, 7, and 10 in November 2001 and April 2002	36
23	Total selenium profiles at sites 15 and 21 in November 2001 and April 2002	28
24	Total selenium concentrations by site at Stewart Lake for each sampling date since 1995	42
25	Correlations between selenium and site during the monitoring period 1995-2002	46
26	Annual geometric mean total selenium concentrations (USGS laboratory) in Stewart Lake surface sediments as defined by north-south site groupings	48

List of Tables		
Number	Title	Page
1	Percent distribution of selenium in Stewart Lake samples from April 2002	5
2	pH of Stewart Lake sediments	6
3	Post-lime changes in predominant selenium species and total selenium at site 21 during April 2002	7
4	Experimental flood plot physical data	27
5	Statistical summary of 2001 density samples	28
6	Summary of selenium changes in the depth profiles of the 2 experimental flood plots at Stewart Lake in Aug.-Sept. 2002	29
7	Summary of Areal Changes in Selenium during the 2002 Flooding Experiments	31
8	Flood plot and site 21 water depths (in.) during the 2002 flooding experiments	31
9	Summary of Changes in Surface (0-6 inches) Selenium in the 4 Quadrants at Site 21 during the 2002 Flooding Experiments	32
10	Changes in the total selenium mass in the surface layer at site 21	32
11	Stewart Lake Recent Sediment QA/QC data	34
12	Total selenium (ppm) in surface samples collected at the 20 permanent monitoring sites from November 2001 through October 2002	40
13	Comparison of November 2001, April 2002, and October 2002 total selenium concentrations at 20 sites at Stewart Lake	40
14	Wilcoxon signed-ranks tests of post-flood total selenium between years	41
15	Pearson correlations of total selenium (USGS) with sample date and year for each of the 20 permanent monitoring sites at Stewart Lake (significant correlations [probability of a > r < 0.05] are highlighted)	44
16	Discriminant analysis of total selenium distribution by site number groupings	46